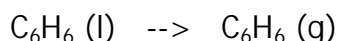


1999 Exam #1 – Chem 36 Exam Questions/Answers

1. In order to keep carbonated water carbonated, it is necessary to keep a high pressure of CO₂ over the solution. If the concentration of CO₂ in "sparkling water" is 0.147 mol/L, what must be the partial pressure (in atm) of the CO₂ above it? The Henry's law constant for CO₂ at 25 °C is 1.65 x 10³ atm-L/mol. (You may assume the density of the solution is 1.00 g/mL.)

$$P_{\text{CO}_2} = \underline{243. \text{ atm}}$$

2. Benzene (C₆H₆) shows up quite frequently in your text in a number of chapters and, besides being quite useful as an organic synthetic reagent, is a suspected carcinogen (oh boy!). The vaporization of benzene is represented by the expression below:



- a. Using the thermodynamic data provided, calculate the standard molar enthalpy of vaporization ($\Delta H^\circ_{\text{vap}}$) for benzene.

$$\Delta H^\circ_{\text{vap}} = \underline{33.90 \text{ kJ/mol}}$$

- b. Based on the enthalpy of vaporization that you calculated above, is this process exothermic or endothermic?

Since $\Delta H^\circ_{\text{vap}}$ is positive, process is endothermic

- c. Calculate the change in standard molar free energy (ΔG°) at 25 °C for this process.

$$\Delta G^\circ = \underline{5.16 \text{ kJ/mol}}$$

- d. Based on the free energy calculated in part c, is the vaporization of benzene a spontaneous process at 25 °C?

ΔG° is positive, so process is not spontaneous at 25 °C

- e. Would you expect an increase or decrease in the entropy of this system as a result of the vaporization of benzene? (Don't do any calculations! Base your answer only on inspection of the reaction equation.) Briefly explain.

This is a phase change from a more ordered state (liquid) to a less ordered state (gas). Since a less ordered state (gas) has more possible microstates available, it has a greater entropy. Thus, for the vaporization of benzene, entropy increases.

- f. Using the thermodynamic data provided, calculate the standard molar entropy change (ΔS°) for the vaporization of benzene.

$$DS^\circ_{vap} = \underline{94.28 \text{ J/K}}$$

- g. Compare the value of ΔS° you calculated with the value from Trouten's Rule. Explain whether you expect there to be significant deviations from the Trouten's Rule value.

Trouten's Rule says that DS°_{vap} should be about 88 J/K - the actual value here is a little bit higher, but within reason for such an estimate. This is expected as there are no unusually large intermolecular forces operative in a solution of benzene (it is a nonpolar molecule).

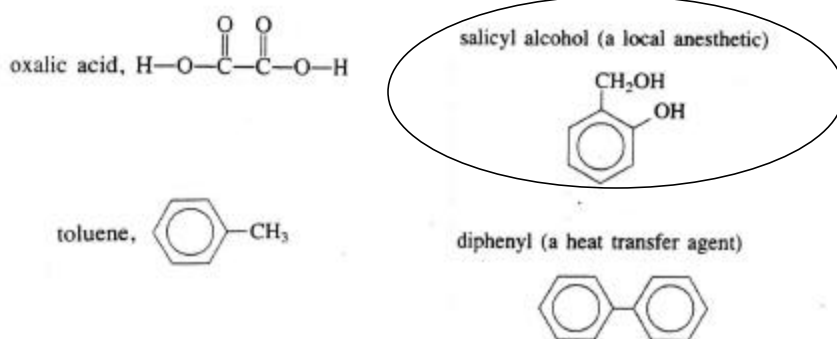
- h. Using data from your above answers, calculate the boiling point of benzene (i.e., at what temperature does the vaporization of benzene become spontaneous?).

$$T_b = \underline{352.9 \text{ K}} \text{ or } \underline{79.7 \text{ }^\circ\text{C}}$$

3. Calculate the partial pressure of benzene (in torr or mm Hg) above a solution obtained by mixing 45.8 grams of benzene (MW = 78.114 g/mol) with 25.5 grams of toluene (C_7H_8 - MW = 92.141 g/mol) at 25 $^\circ\text{C}$.

$$P_{\text{Benzene}} = \underline{64.6 \text{ torr}}$$

4. a. Since we're on the subject of benzene, let's look at some solubility considerations. Circle the compound(s) below which you would expect to be moderately soluble in both benzene and water. Explain (briefly) why. (Note: "Like dissolves like" is NOT a suitable explanation!)



Salicyl Alcohol is one of two compounds that can participate in hydrogen bonding when dissolved in water. The other compound that can hydrogen bond, oxalic acid, is too polar to be soluble in benzene, so it is not an option. The benzene ring component of salicyl alcohol will facilitate its solubility in benzene.

- b. Would you expect the benzene solutions resulting from the dissolution of the compounds that you selected in part a (above) to be ideal solutions? Explain.

No, a solution comprised of salicyl alcohol dissolved in benzene would NOT be an ideal solution. Why? The intermolecular forces between benzene and salicyl alcohol would be considerably different than benzene-benzene or salicyl alcohol-salicyl alcohol IMFs.

5. a. Suppose that an unknown compound is dissolved in 557.3 grams of benzene. How many moles of the compound must be dissolved in the solution in order to reduce benzene's freezing point from 5.53 °C to 3.10 °C?

$$n_{\text{cmpd}} = \underline{0.28 \text{ mol}}$$

- b. Would you expect the molality and the molarity of this solution to be very different? Explain. (Note: you don't need to calculate the molarity to answer this!)

Molality and molarity have very similar values for dilute solutions. From the previous problem, we know that the molality is about 0.5 mol/kg solvent, so this is a dilute solution. We would expect, then,

the molarity to be of a similar value (i.e., about 0.5 mol/L). Realize, however, that since the solvent (Benzene) does not have a density of 1 g/mL, that kg solvent does not necessarily translate to an equivalent volume (L) of solvent . . . but this density difference will not be overwhelming.

- c. If the solution described in part a of this question was prepared by adding 11.734 grams of the solute to the benzene, calculate the molecular weight of the unknown compound.

$$\text{MW} = \underline{42 \text{ g/mol}}$$

6. a. NaCl(aq) isotonic with blood is 0.90% NaCl (mass/vol). For this solution, calculate the osmotic pressure (in torr or mm Hg) at 37. °C (normal body temperature).

$$P = \underline{7.8 \text{ atm}}$$

- b. Briefly describe (and explain) what would happen to a red blood cell that was placed into distilled water.

Since the concentration of NaCl is greater inside the cell than outside, solvent (water) would flow INTO the cell . . . until the concentration inside the cell equalled that outside the cell. Since this final condition can never be attained (there will always be NaCl inside the cell), the flow of water into the cell will continue until the cell walls burst and the cell explodes (!).

EXTRA CREDIT! Although I have given you the vapor pressure of pure benzene at 25 °C on your formulae sheet, it is also possible to calculate it directly from the thermodynamic data that I've provided. For 5 big extra credit points (and a chance at what's behind door number 2 . . .), calculate the vapor pressure of benzene at 25 °C using the thermodynamic values given for benzene. How does this calculated value compare with the value that I've given you? NOTE: you will likely need to use some equilibrium and free energy relationships to solve this one . . .

From the thermodynamic data given, one can calculate:

$$P_{\text{benzene}} = \underline{94.8 \text{ torr}}$$